# Autonomous Ship Detection System

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## LONG-TERM GOALS

Due to the events of September-11-2001 the U.S. Coast Guard has requested and received from the Office of Naval Research the approval to change the focus of the original proposal from autonomous ship detection to the use of Autonomous Underwater Vehicles (AUV) for Port Security operations. This decision was approved in mid March-2002 and work commenced the beginning of April- 2002.

Our new goal is to demonstrate the efficacy of using AUVs to scan underwater surfaces (ship hulls, docks, etc.) to detect anomalies requiring additional investigation for risk assessment. This could lead to an effective system for scanning large volume port traffic in a consistent and efficient (timely) manner.

A further goal is to demonstrate to the Coast Guard the advantages of using AUV technologies to provide significantly greater undersea access.

## OBJECTIVES

The primary objective is to integrate the updated laser system ROBOT (ONR#N00014-01-1-0279) developed by University of South Florida (USF) with the underwater vehicle ROVEX to support the evaluation of the laser package with regards to the Coast Guards Port Security needs for scanning a variety of underwater surfaces (ship hulls, docks & harbor bottoms).

Investigate vehicle navigation issues with regards to supporting the scanning and data processing requirements. Based on mission requirements and the testing results, develop an AUV performance specification data sheet for the use in the procurement of commercial AUVs. Develop operational procedures for conducting ship hull, dock and harbor bottom scans using AUVs.

## APPROACH

The Coast Guard has selected a laser based scanning instrument developed by the Center for Ocean Technology (COT) located at the University of South Florida (USF) (ONR#N00014-01-1-0279) as the primary sensor technology for initial evaluation. This prototype laser based system for creating 3-D imagery of the ocean bottom was initially intended and developed for ONR's mine countermeasures program. This system, known as the Real-time Ocean Bottom Optical Topographer (ROBOT), uses a bistatic line imager to determine bottom relief. Successive line image acquisitions enable construction of a 3-D bottom topography map. The system was upgraded to improve its original operating characteristics. Upgrades included extending the sensor's ability to function in moderately turbid waters ($c \leq 0.6$) and provide dimensionally accurate 3-D representations of imaged objects in addition to adding a fluorescence imaging system to the instrument. The capability to monitor the fluorescence of a surface (bottom/ship hull etc.) will aid in minimizing "false positives" since inorganic (i.e. man-made) objects do not fluoresce. Vehicle and sensor designs will be modified to permit operation of the instrument in a broader range of applications (e.g. ship hull inspection, obstacle avoidance). The result will be a flexible, compact, and relatively inexpensive sensor capable of providing real-time range, intensity and biofluorescence data at vehicle speeds approaching our 20-knot goal.

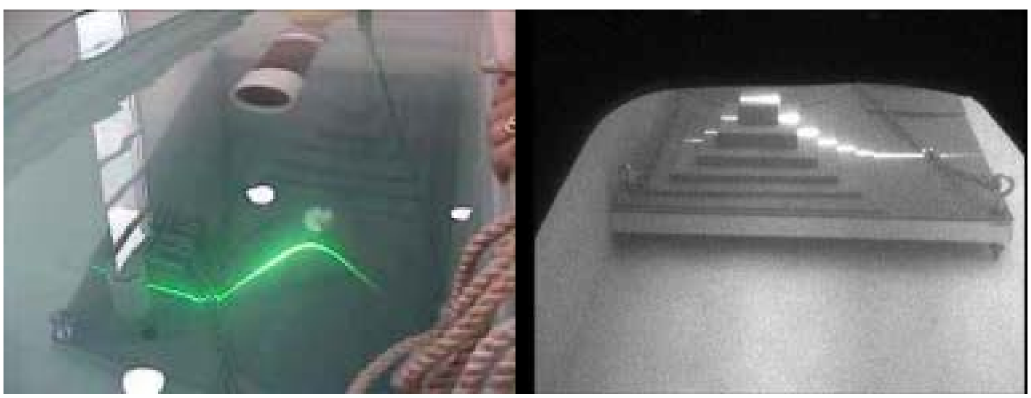

***Figure 1. Tank test of the laser scanning system ROBOT supported by the underwater vehicle ROVEX.***
***[The image on the left shows the green laser "painting" the test cone target, while the image on the right is the view from ROBOT's camera.]***

The COT laser system was then integrated into a 21" (53 cm) diameter AUV payload that mates with the underwater vehicle ROVEX. The autonomously guided underwater vehicle ROVEX was selected as the initial testing platform since the vehicle design supports a real time Ethernet and video connection that is extremely useful in developing subsea sensors. The use of this vehicle as an "AUV" test platform will terminate upon receipt of COT's commercially produced AUV scheduled for fall of 2003.

***Figure 2. ROVEX with ROBOT payload***
***[The Laser imaging sensor ROBOT as an AUV payload connected to the autonomously guided underwater vehicle ROVEX. The white surface communications tow float is shown in the foreground.]***

ROVEX will be used to support the investigation of the following sensor issues:

1. Verify the ROBOT's in water camera field of view and light sensitivity.
2. Video resolution and quality in known turbidity levels (C-values).
3. Identify working altitudes.
4. Performance characteristics in high light levels and fluorescence monitoring.
5. Collect raw video data sets of know targets under known conditions (turbidity & light levels) to be used as known test cases for software development.

## WORK COMPLETED

The at sea support of the laser imaging system ROBOT onboard the underwater vehicle ROVEX required several hardware and software modification to ROVEX not required for the original Autonomous Ship Detection System proposal. The main modifications included:

1. Installed a Crossbow Attitude Heading Reference System (AHRS) in order to provide attitude data for ROBOT.
2. Modified ROVEX software to process the raw RDI Doppler Velocity Log (DVL) data using the Crossbow AHRS and FSI CTD data.
3. Designed and assembled a high quality subsea video recorder package. This assembly records video onto SONY Digital 8 format with SMPTE time codes (LTC).
4. Modified the software to synchronize all ROVEX computers (subsea & topside) and the video time code generator to GPS time. This allows any subsea or topside collected data to be matched to any individual video frame.

A subsea laser (or sonar) test target was designed and fabricated (figures 2 and 3) in order to meet the following requirements:

1. Allow for rapid change out of individual target components (panels).
2. Easy deployment & recovery in water depths up to 40 meters (preferably without divers).

The test frame was constructed of 3” box aluminum and plastic (PVC) test panels that were painted gray to provide the required reflectance prosperities. The assembly was deployed and recovered using acoustic releases that negated the use of SCUBA divers.

***Figure 3. Laser subsea test frame assembly (without cone target)***
***[The frame is 3 meters long by 1.2 meters wide. The vertical acoustic release assembly is at the opposite end with an orange recovery float directly above the acoustic release.]***

**RESULTS**

The laser scanner ROBOT was assembled and installed into a 21-inch (53 cm) payload that was successfully integrated with ROVEX. ROVEX was upgraded as detailed under the Work Completed section of this document. The ROVEX-ROBOT assembly was successfully operated in Tampa Bay and in the coastal waters off of Indian Rocks Beach (near Tampa Bay). Figure 4 is a still captured from video collected subsea by the subsea digital video recorder package receiving composite (NTSC) video from ROBOT’s CCD video camera.

***Figure 4. Underwater image of the laser test frame assembly***
***[Recorded by the ROVEX supporting the laser scanner ROBOT at an altitude of 3 meters with natural light 30 minutes after sunrise. The test frame was located in 12 meters of water with a water turbidity corresponding to $C \approx 0.45$ meters$^{-1}$.]***

The Indian Rocks Beach operations also allowed verification that an underwater vehicle could be acoustically tracked using an ultrashort baseline sonar system and navigated accurately enough to fly over a small test target (1.2 m x 3 m) consistently from ranges of 250 meters. This range of 250 meters is approximately what is anticipated for the working ranges from the Coast Guard support vessel to the AUV during actual hull scanning missions. Additional testing was conducted in Tampa Bay in turbid waters (C = 1.99). The results of these tests are shown in figure 5.

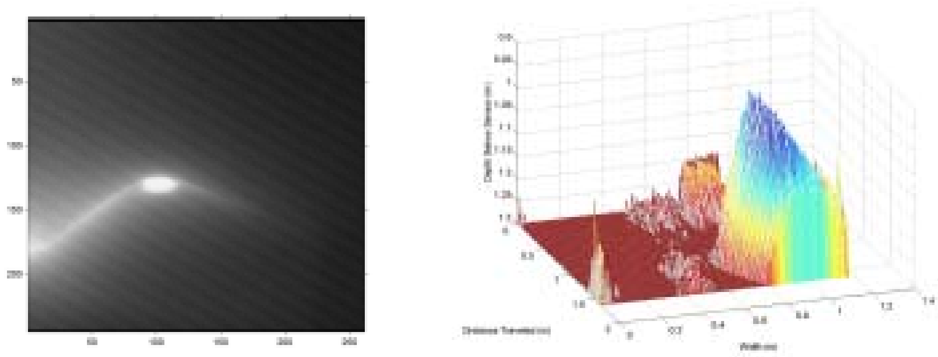

***Figure 5. Test target in Tampa Bay***
***[The video captured image on the left is of the test target cone scanned at a range of 1.5 meters (C= 1.99 $m^{-1}$ ). The image on the right is the vector product from the laser scanning system. For comparison refer to figure 1 image on the left (tank Test).]***

The ROVEX-ROBOT operations also allowed us to start developing our requirements for a 12-3/4" diameter AUV.

## IMPACT/APPLICATIONS

The Coast Guard clearly needs a quick, efficient and cost affective method to scan underwater surfaces to look for potential sabotage as required to protect American seaports. The use of AUVs provides this by acting as a force multiplier (using several AUVs at once), provides a very stable sensor platform, easily supports a wide variety of sensors (Laser, Sonar, video, TNT, etc.) and minimizes or negates the risk to Coast Guard divers currently required for ship hull inspections.

## TRANSITIONS

## RELATED PROJECTS

The Advanced Underwater Port Security System project (ONR# N00014-02-1-0859) will continue the progress from this project by producing a final working system that meets the Coast Guard's physical and operational requirements. This project will also result in the specifications for the vehicles to be produced by the Autonomous Underwater Vehicle for Homeland Defense project (ONR# N00014-02-1-0719) and the Autonomous Underwater Vehicle for Homeland Defense and Research Support (ONR# N00014-02-1-0825). The ROBOT (ONR#N00014-01-1-0279) will be the detection instrument.

The upgrade of the underwater vehicle ROVEX will support the development of other ONR funded sensors such as the underwater Mass-Spectrometer (ONR# N00014-98-1-0154), SIPPER a partial imager (ONR# N00014-96-1-5020) and other newly developed sensors such as COT's TNT sensor.